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Original Research

Transportation and shaping ability of 3 canal anatomy-friendly systems in curved root canals

Transportation and shaping ability

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Abstract

Aim: In this study, we aimed to compare the shaping efficacy of the TruNatomy (TRN), XP-endo Shaper (XPS), and 2Shape (TS) NiTi rotary systems in terms of canal transportation, centering ratio, and removed dentin volume using cone beam computed tomography (CBCT).

Material and Methods: Sixty mesial root canals of mandibular first molar teeth with a curvature angle of 20-40° and curvature radius of 4-6 mm were allocated to three groups (n=20). Instrumentation was performed in compliance with the manufacturer's instructions. CBCT images were taken in the same position before and after instrumentation. Canal transportation and the centering ratio were calculated at 3, 6, and 9-mm distances from the apex. Data were statistically analyzed.

Results: TS group had significantly higher transportation ($P<0.05$) and there was no significant difference between the TRN and XPS groups. In terms of centering ability, no significant difference was detected between the groups ($P>0.05$). The volume of removed dentin was significantly lower in the TRN group ($P<0.05$) and there was no significant difference between the XPS and TS groups.

Discussion: XPS and TRN groups showed less transportation than TS, whereas the centering ability was similar for all groups. In addition, the TRN group removed significantly less dentine, supporting the minimally invasive endodontic approach.

Keywords

Centering Ratio, Cone-Beam Computed Tomography, Root Canal Volume, Transportation, TruNatomy

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Introduction

The objective of a successful root canal preparation is to remove the infected dentine, to prepare a sufficient space for effective irrigation, and to create a conical form for appropriate canal obturation, preserving the original canal anatomy [1]. However, the complex anatomy of the root canal makes it difficult to achieve ideal shaping, especially in curved canals [2]. Instrumentation procedures tend to deflect the root canal from its original axis and may lead to procedural errors, including lodging, zipping, strip perforation and transportation [3]. Therefore, with the improvement of thermomechanical production stages, more flexible NiTi rotary instruments that can provide better centering ability and preserve the original canal anatomy have been developed [4].

TruNatomy (TRN) (Dentsply Sirona, Ballaigues, Switzerland) is a new-generation heat-treated super elastic NiTi rotary system recently released on the market. Compared with traditional NiTi rotary instruments, the TRN has a smaller core structure and reduced shape memory characteristics. Each instrument has a regressive taper, which allows each instrument to maintain a maximum flute diameter of 0.8 mm [5].

XP-endo Shaper (XPS) (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) is a single-file system made of Max Wire alloy. This alloy is in the martensitic form at room temperature, and the phase transformation occurs at 35°C, thus it transforms into an austenitic form at body temperature, causing the file to become curved. This unique design preserves the three-dimensional configuration of the root canal anatomy, while allowing a gradual increase in the working area under the temperature effect [6].

The 2Shape (TS) (MicroMega, Besancon, France) is manufactured from T-Wire alloy. It has been reported that the use of T-wire alloy provides better shaping ability in curved canals [5].

In this study, it was aimed to compare the shaping ability of novel TruNatomy rotary system with a single instrument XP-endo Shaper and 2Shape rotary system consisting of 2 instruments. The null hypothesis is that there are no differences between TRN, XPS, and TS in terms of shaping efficacy in curved root canals.

Material and Methods

Local ethics committee approval was obtained from the Ethical Review Committee under the Research Foundation [removed for blind peer review] (No: 2019/164).

Sample Selection and Preparation

In this study, 60 mesial canals obtained from freshly extracted mandibular first molar teeth were used. The inclusion criteria for the study were as follows: the presence of 2 canals with a curvature angle of 20-40° (according to the Schneider method) [7], and a curvature radius of 4-6 mm (according to the Pruett method) [8], terminating with two separate foramina in the mesial root (type IV Vertucci canals); the absence of obstructions in the root canal; having initial apical diameter of 0.15 mm; completed root development; and no resorptions, cracks, or fractures in the root; and the presence of similar root lengths (17 ± 2 mm).

Tissue residues on the outer surface of the roots were removed using a periodontal curette. The teeth were kept in physiological saline at + 4°C during the study. Traditional access cavity was performed with an Endo-Z bur (Dentsply Maillefer, Ballaigues, Switzerland), and the mesial canals were explored with #10 K file (Dentsply Maillefer, Ballaigues, Switzerland). Working length was determined by subtracting 1 mm from the length at the time the file was first seen. To ensure standardization, the occlusal surfaces of the teeth were flattened under water cooling and the working length was fixed to 18 mm. The samples were embedded in acrylic blocks up to the level of the enamel-cement junction.

A fixed system was designed to obtain stable cone beam computed tomography (CBCT) images of the samples in the same position. The CBCT scans were obtained using a Planmeca system (Promax 3D Classic, Helsinki, Finland) with scanning parameters of 90 kV, 10 mA, 12 sec and 100 μm voxel size. The field of view (FOV) of the detector panel was 50x50 mm. The Planmeca Romexis Viewer software was used for processing the CBCT images. The obtained images were reconstructed with 0.1-mm section thickness. The curvature angles and radii of the samples were measured on the preoperative CBCT images and the selection of sample was made. The selected samples were divided into three groups with similar curvature angles and radii.

Root Canal Instrumentation

Before the instrumentation procedure, all samples were kept in a 37°C water bath for 30 minutes, and the irrigation solutions were also heated to 37°C to maintain the intracanal temperature during preparation. All instruments were used according to the manufacturer's instructions in continuous rotation movement, using a VDW Gold endodontic motor (VDW GmbH, Munich, Germany) and each instrument was used in only two canals.

In the TRN group, respectively, Orifice Modifier (20/0.08), Glider (17 /0.02), Small (20/0.04), and Prime (26/0.04) files were used at 500 rpm and 1.5 Ncm settings. In the XPS group, a #15 K file was used to obtain a glide path before using the XPS file (30/0.04). Instrumentation was performed at 800 rpm and 1 Ncm settings. When the 30/0.04 gutta-percha fit the canal perfectly, instrumentation was finished. In the TS group, after establishing the glide path with a #15 K file, instrumentation was performed using a TS1 (25/0.04) and TS2 (25/0.06) at 300 rpm and 2 Ncm settings. In all groups, the root canals were irrigated with 2 mL of warmed NaOCl (2.5%), using a 30-G needle (KerrHawe SA, Bioggio, Switzerland) after each file change. The final irrigation was performed with 5 mL of NaOCl (2.5%) followed by 5 mL of distilled water.

CBCT Measurements

After instrumentation, postoperative CBCT scans were performed using the same parameters as in the initial imaging. Measurements were made at 3, 6, and 9-mm distances from the apex, considering the start and end points of the canal curvature. On preoperative and postoperative CBCT images, the shortest distance between the outer border of the root and the canal wall was measured from four different regions in axial sections by a single observer twice, 3 weeks apart, and the average values were recorded as the final data (Figure 1).

Transportation and centering ratios were determined using the formulas suggested by Gambill et al. [9]:

Transportation in the buccolingual direction = (B1-B2) - (L1-L2),
Transportation in the mesiodistal direction = (M1-M2) - (D1-D2)
Centering ratio in the buccolingual direction = (B1-B2) / (L1-L2) or (L1-L2) / (B1-B2),
Centering ratio in the mesiodistal direction = (M1-M2) / (D1-D2) or (D1-D2) / (M1-M2).

B1, L1, M1, and D1 indicate the shortest distance between the buccal, lingual, mesial, and distal borders of the root, and the canal wall before instrumentation and B2, L2, M2, and D2 indicate the shortest distances after instrumentation. According to these formulas, the result of 0 indicates that there is no canal transportation. Positive values indicate transportation towards buccal or mesial directions, and negative values indicate transportation towards lingual or distal directions. A centering ratio of 1 shows perfect centering. Any value other than 1 indicates that the canal is not centered. As the centering ratio gets closer to zero, the instrument's centering ability decreases.
To determine the removed dentine volume, the CBCT images were transferred to the InVesalius program (version 3.1; Centro de Tecnologia da Informação Renato Archer, Campinas, SP, Brazil) and the root canal volumes were calculated by a single observer. The volume of removed dentine (mm3) was calculated by subtracting the preoperative volume of the root canal from the postoperative volume, referencing Hashem et al. [10] (Figure 2).

Statistical analysis

All data were analyzed using the SPSS (SPSS Inc., Chicago, IL) program. One-way ANOVA was used for normally distributed data and the Kruskal-Wallis test was used for non-normally distributed data in the comparison of transportation values and centering rates at different levels and in different directions according to the groups. One-way ANOVA was used for the comparison of the removed dentine volume by groups. P<0.05 was accepted to indicate statistical significance.

Ethical Approval

Ethics Committee approval for the study was obtained.

Results

According to the total mean transportation values, the TS group showed significantly higher transportation (P<0.05); the difference between the TRN and XPS groups was not significant. There was no significant difference between the groups at any level in the BL direction. In the MD direction, there was no significant difference between the groups at the 3-mm level, but at the 6-mm level, the TS group exhibited significantly more transportation than the TRN group, and at the 9-mm level, more than both the TRN and XPS groups (Table 1).
There was no significant difference between the groups at any level and direction in terms of centering ratio (P>0.05) (Table 2).
The volume of removed dentine in the TRN group was significantly lower compared with the others (P<0.05). The difference between the XPS and TS groups was not significant (Table 3).

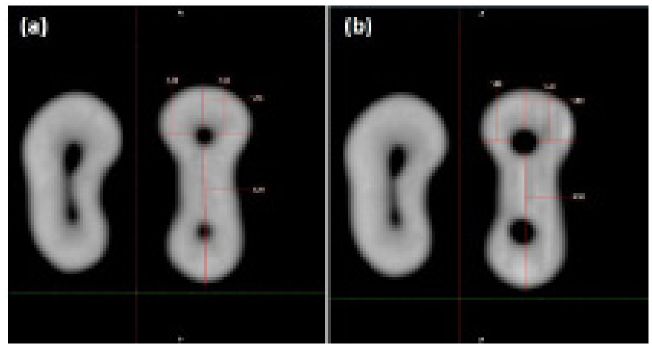

Figure 1. Canal transportation and centering ratio measurements (a) before instrumentation and (b) after instrumentation.

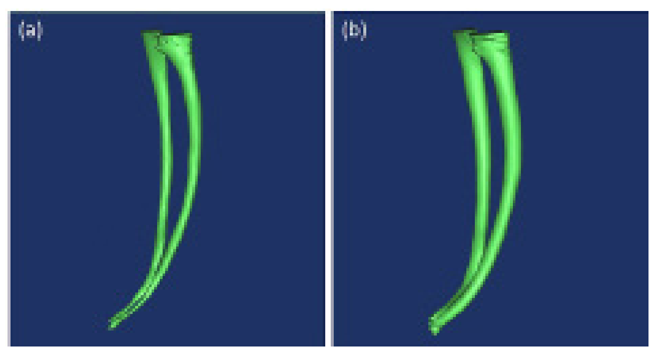

Figure 2. Volumetric changes measurements (a) before instrumentation and (b) after instrumentation.

Table 1. The mean ± standard deviation and median (minimum – maximum) values for the transportation (mm).

Group	3 mm		6 mm		9 mm		Total
	BL	MD	BL	MD	BL	MD	
TruNatomy	0,061 ± 0,043	-0,041 ± 0,056	-0,108 ± 0,072	0,046 ± 0,047[a]	0,072 ± 0,068	-0,072 ± 0,083[a]	0,066 ± 0,066[a]
	0,09 (0 - 0,1)	0 (0 - 0,19)	0,09 (0 - 0,29)	0,045 (0 - 0,1)	0,09 (0 - 0,19)	0,09 (0 - 0,3)	0,09 (0 - 0,3)
XP endo Shaper	0,069 ± 0,06	-0,041 ± 0,056	0,075 ± 0,059	-0,056 ± 0,064[ab]	0,067 ± 0,084	-0,064 ± 0,079[a]	0,062 ± 0,067[a]
	0,09 (0 - 0,19)	0 (0 - 0,19)	0,09 (0 - 0,19)	0,045 (0 - 0,19)	0,05 (0 - 0,31)	0 (0 - 0,2)	0,09 (0 - 0,31)
2Shape	0,066 ± 0,07	0,064 ± 0,061	0,12 ± 0,09	0,103 ± 0,08[b]	0,128 ± 0,109	-0,149 ± 0,093[b]	0,105 ± 0,089[b]
	0,09 (0 - 0,2)	0,09 (0 - 0,19)	0,1 (0 - 0,39)	0,1 (0 - 0,29)	0,1 (0 - 0,3)	0,19 (0 - 0,39)	0,1 (0 - 0,39)
P	0.921*	0.353*	0.285**	0.017*	0.064*	0.004*	<0.001*

* One-way ANOVA, ** Kruskal-Wallis test; In each column, different superscript letters indicate a statistically significant difference (P < 0.05).

Table 2. Mean ± standard deviation and median (minimum – maximum) values of the centering ratio.

Group	3 mm		6 mm		9 mm		Total
	BL	MD	BL	MD	BL	MD	
TruNatomy	0,442 ± 0,411	0,638 ± 0,456	0,283 ± 0,346	0,59 ± 0,436	0,553 ± 0,41	0,547 ± 0,438	0,509 ± 0,425
	0,1 (0,1 - 1)	1 (0,05 - 1)	0,1 (0,03 - 1)	0,75 (0,1 - 1)	0,5 (0,05 - 1)	0,5 (0,05 - 1)	0,5 (0,03 - 1)
XP endo Shaper	0,41 ± 0,444	0,638 ± 0,456	0,453 ± 0,408	0,585 ± 0,443	0,567 ± 0,445	0,693 ± 0,372	0,558 ± 0,431
	0,1 (0,05 - 1)	1 (0,05 - 1)	0,313 (0,05 - 1)	0,75 (0,05 - 1)	0,7 (0,05 - 1)	1 (0,05 - 1)	0,5 (0,05 - 1)
2Shape	0,532 ± 0,446	0,455 ± 0,457	0,342 ± 0,325	0,528 ± 0,333	0,455 ± 0,398	0,497 ± 0,283	0,468 ± 0,377
	0,415 (0,05 - 1)	0,1 (0,05 - 1)	0,218 (0,02 - 1)	0,5 (0,03 - 1)	0,5 (0,03 - 1)	0,5 (0,03 - 1)	0,5 (0,02 - 1)
P*	0.658	0.351	0.323	0.843	0.655	0.188	0.241

* One-way ANOVA.

Table 3. The mean ± standard deviation values of the removed volume of the dentine (mm^3).

Group	Mean ± SD	P value
TruNatomy	1.006 ± 0.527[a]	
XP endo Shaper	2.309 ± 1.03[b]	<0.001
2Shape	2.899 ± 1.02[b]	

SD, Standard Deviation

Discussion

During instrumentation, it is aimed to achieve a conical form from apical to coronal, as well as to maintain the original anatomic configuration of the canal. NiTi rotary systems allow for easier and faster instrumentation besides preserving the original canal configuration, leading to considerably fewer procedural errors [4].

Extracted human teeth were used in our study because their in vitro reliability is closest to clinical conditions. In clinical conditions, the interference of the cervical dentine causes stress on files during canal instrumentation [11]. To mimic this condition, crowns were not removed in this study.

Although the small voxel size of Micro-CT is effective in evaluating shaping efficacy, such systems are expensive and require longer screening and reconstruction times compared with CBCT, which is an effective non-invasive imaging method to calculate the quantity of the removed dentine, canal transportation, and the canal centering ratio [10, 11].

In studies evaluating the quantity of transportation and centering ratios, there is no consensus on the measurement distances from the apex, and the fact that the maximum curvature points in all teeth will not be at the same level should be taken into account in ensuring standardization [12]. Therefore, in this study, the evaluation levels were decided as 3, 6, and 9 mm after determining between which levels the maximum curvature point was for each canal. Additionally, to obtain standard conditions in terms of canal curvature, besides the curvature angle, the radius of curvature was also taken into consideration and with curvature angles of 20-40° and radius of 4-6 mm were selected.

The apical diameter reached after instrumentation is also an important criterion in terms of standardization. The XPS file is a single-file system that has an ISO 15 tip size and 0.01 taper, and forms a canal with the apical size of ISO 30 and the taper of 0.04 at the end of the instrumentation procedure [13]. To ensure the final apical diameters of the samples were as close as possible, in TRN and TS groups, TRN Prime (26/0.04) and TS2 (25/0.06) were used as final instruments, respectively.

It has been reported that the temperature in the root canal might affect the clinical performance of all types of NiTi instruments [14]. Therefore, in this study, all groups were kept in a warm bath at 37°C before being used and the intracanal temperature was maintained using irrigation solutions heated to 37 ° C to simulate clinical conditions and provide standardization between groups.

According to the findings of this study, the TRN navigated in the center of the canal, allowing for root canal instrumentation with minimal transportation, due to the improved flexibility and less shape memory due to the applied heat treatments [5]. In addition, the TRN removed significantly less dentine compared with the other groups in this study. This can be attributed to the working principle of the system, supporting minimally invasive root canal preparation. In consistence with our findings, in a micro-CT study by Perez Morales et al., they found that TRN had touched the least area on the canal surface compared with WaveOne Gold, Reciproc Blue, TruShape, IRace and XPS [15].

Wu et al. [16] showed that apical canal transportation of less than 0.3 mm would have a minimal effect on the prognosis of endodontic treatment. Although all rotary systems used in this study resulted in some transportation at all levels, the BL and MD transportation values were less than 0.3 mm in all groups. Although there was no significant difference between the BL transportation values at any level among the groups, significant differences were observed between MD transportation values at the 6 and 9-mm levels. This is a predictable result, considering that the canal structure is wider in the BL direction than in the MD direction, and the canal curvatures of the lower molars are seen more frequently in the MD direction. This is consistent with the results of similar studies [17,18].

According to the total transportation values, although the TS group resulted in significantly more transportation compared with the TRN and XPS groups, the difference between the TRN and XPS groups was not significant. Thus, the null hypothesis tested in the present study was rejected. Compatible with that study, the 0.06 taper of the final TS instrument compared with the 0.04 taper of the TRN and XPS groups may explain the significantly higher transportation values of the TS group in our study. In a micro-CT study, [19] comparing different systems in the mesiobuccal canals of maxillary molars with a curvature of 25-40°, TRN and XPS exhibited similar transportation and centering ability, which is consistent with the current study.

Similarly, Pérez Morales et al. compared the shaping ability of different systems in mesial canals of mandibular molars using micro-CT and found no significant difference between the XPS and TRN groups [15].

In studies comparing the XPS and different NiTi rotary systems, it has been shown that the XPS displays lower transportation and better centering ability owing to the adaptive core technology [6]. In our study, XPS showed significantly less transportation compared with the TS group. This finding can be attributed to the adaptive core technology, which allows for the preservation of the original anatomy and curvature of the root canal. Besides, the booster-type tip design is also thought to help the instrument provide more central shaping.

In their study examining the shaping efficacy of TS and ProTaper Gold in the mandibular first molars using CBCT, Singh et al. [20] reported that the triple-helix cross-section design and the T-wire technology that improved the flexibility of the TS system allowed for overcoming the curvatures of the canals more effectively, resulting in less transportation and better centering ability. However, in our study, although the TS group showed similar centering ability with the other groups, this resulted in significantly higher transportation values compared to the other groups. Despite similar tooth samples and evaluation methods, these contradictory results between the two studies can be attributed to the difference in design and metallurgical properties of the systems with which the TS system was compared.

Investigating the shaping efficacy of new NiTi systems with different designs and kinematics is important in understanding how these differences affect clinical performance. Further clinical studies are required because in vitro studies do not fully reflect clinical performance.

Conclusion

Within the limitations of this study, centering abilities were similar for all groups, but the XPS and TRN groups showed significantly better performance compared with the TS group in terms of transportation. The TRN system removed significantly less dentine, supporting the minimally invasive root canal preparation.

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Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest
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